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Abstract

DEVELOPMENTS IN BOILING WATER REACTORS

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Since the second Geneva Conference in 1958 on the Peaceful Uses of Atomic Energy, boiling water reactor power plants have been accepted as a commercial reality competing with other forms of energy for electrical power production in several countries. This paper discusses the key factors that have brought about the evolution of this reactor concept.

Today, 12 U.S.-designed boiling water nuclear power stations have been commissioned and operated, representing 584 300 installed net kw. Six new BWR nuclear power stations, adding 1 995 000 net kw of installed capacity, are in various stages of design and construction. Initial designs were conservative as nearly every reactor placed into operation is capable of producing more power than initially expected.

The evolution of the boiling water reactor has followed a process of simplification in design resulting from operating and test performance. Key technical features which are important to equipment simplification and improved safety include the use of the single cycle with steam separation inside the reactor vessel and a pressure suppression type of containment. Much emphasis is placed on reactor control for safety and on the reliability of nuclear equipment.

Observed results from the operation of BWR cores has demonstrated the practicality of achieving a considerable degree of power flattening by proper control rod programming and scatter loading of replacement fuel. The data accumulated allows accurate prediction of lattice parameters and reactivity performance. Earlier segmented fuel rod designs are superseded by straight-through rods. Currently, reactors are licensed with burnout margins of 1.5 in contrast to earlier margins of 2.0. Design core exit steam qualities have increased from 5 to 9-1/2 weight per cent.

In the BWR, Zircaloy is the most suitable material for fuel element cladding from the standpoint of overall performance. The direction of development is toward thinner cladding for economy with integrity to burnup exposures in the range of 20 000 MWD/ton. Experimentally, fuels have demonstrated satisfactory performance above this range.

Some early fears concerning the boiling water reactor are proven to be unfounded. The use of reactor steam directly in the turbine has been satisfactory without excessive radiation, corrosion or maintenance problems. The reactor has operated stably with high voids and responded well to all transient operating conditions. Core power distributions are readily measured and regulated. The handling of off-gases and other waste is satisfactory - well within established legal limits.

Future trends in the BWR are in the direction of further equipment simplification, higher core power densities and improved steam conditions. Reduced movable control requirements, improved neutron economy, flatter power distributions and greater exit voids are the major directions for improvements of BWR core designs. The use of nuclear superheat is being vigorously explored with four nuclear superheat prototypes in construction or in operation. Each reload of reactor fuel incorporates the latest technology and economic design changes. Progressive automation of nuclear plant operation can be expected. The trend toward larger unit sizes has been rapid and will continue.